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Computational and Information Sciences and Technology Office

Sciences and Exploration Directorate, Goddard Space Flight Center

In This Issue

A Linux Networx Custom Supersystem will be the next-generation supercomputer for the NASA Center for Computational Sciences. The first stage of the cluster, providing 3.3 teraflops of peak computing power in five closet-sized cabinets, will arrive in June (Photo credit: Linux Networx).

High-Performance Computing

NCCS to Install Next-Generation Supercomputer

The NASA Center for Computational Sciences (NCCS) will soon install the first stage of its next-generation supercomputer, a Linux Networx Custom Supersystem. A 128-node "base unit" is expected to arrive at Goddard Space Flight Center (GSFC) in late June. While providing an initial peak performance of 3.3 teraflops, the system could scale to nearly 40 teraflops in its full configuration.

NCCS system integrator Computer Sciences Corp. (CSC) selected the cluster through a rigorous procurement process involving a nationally distributed Request for Proposals. Designed and optimized for each customer, a Custom Supersystem incorporates a variety of technologies from vendor partners.

Each node in the NCCS base unit contains two Intel dual-core, 3.2 GHz Xeon-Dempsey chips and 4 gigabytes of memory. The system thus has a total of 512 processing units and 512 gigabytes of memory. Its nodes are linked by a 10-gigabit-per-second Infiniband Network from Silverstorm Technologies. Tightly integrated with the compute nodes is a high-performance storage subsystem with

60 terabytes of raw Data Direct Networks storage running the IBM General Parallel File System.

“I am very excited to welcome Linux Networx and their partners to the NCCS team,” said Phil Webster, CISTO’s Lead for High-Performance Computing. “Their high-performance computing expertise and ability to integrate the latest technologies will provide our Earth and space science users with an enhanced processing and data analysis capability for their research.”

The base unit’s peak performance is 100 gigaflops higher than the NCCS’s retiring 1,392-processor HP AlphaServer SC45, with a footprint one-tenth that of the older machine. In July, the NCCS expects to make the cluster available to pioneer users and then begin a 30-day acceptance period that will include baseline benchmarking. While undergoing evaluation, the base unit will run side-by-side with the SC45. NCCS plans call for adding one or two 256-node “scalable units” to the Custom Supersystem by the end of calendar year 2006, increasing aggregate performance to 9.9 or 16.5 teraflops peak. As the system expands, portions of the SC45 will be shut down to accommodate the power and cooling needs.

The Custom Supersystem will provide capacity computing for the NCCS, with most jobs using up to 64 processors. However, it also will be available for capability runs, i.e., for applications that require and can scale to larger numbers of processors. The 1,152-processor SGI Altix 3700 BX2 system, which has twice as much memory per processor, will continue to be the NCCS’s main capability computing platform.

“One of the primary architectural goals of the new cluster environment was to make the transition for the user community as smooth as possible,” said Dan Duffy, Lead Architect for CSC. “We purposefully chose a design that presents a consistent user environment between the Custom Supersystem and the Altix. Users will have access to the same set of tools, modules, and home file systems on both platforms.” For instance, the cluster will have compilers from Intel and PGI, run the PBS Pro batch scheduler, and have both MPI and OpenMP, along with other valuable software tools such as TotalView, MATLAB, and IDL. Moreover, programmers from the NCCS and GSFC’s Software Integration and Visualization Office will assist users in porting and optimizing their codes.

The Custom Supersystem approach also includes the ability to add special processing nodes for analysis and visualization as well as application-accelerator nodes using field-programmable gate arrays, more generally known as FPGAs. The NCCS is evaluating such technologies for its system and will consider user input on what options would be of broadest benefit.

http://nccs.nasa.gov
http://www.linuxnetworx.com

NASA HPC Centers Support Gravitational Wave Breakthrough

Black holes with masses millions of times the mass of a star have been found in the core of our Milky Way and many other galaxies. If they collide, Einstein's equations from the general theory of relativity predict that gravitational radiation – waves of displacement of spacetime – will be radiated away from the collision. Detection of these waves has never been achieved directly, but new detectors are being operated and planned to make this important fundamental test of Einstein's general relativity.

GSFC’s Gravitational Astrophysics Laboratory achieved a breakthrough recently: computation of the signature gravitational wave pattern that is radiated when two black holes that orbit one another experience orbital decay and merge. The solution of this very difficult three-dimensional, time-variable problem in numerical relativity has been a “holy

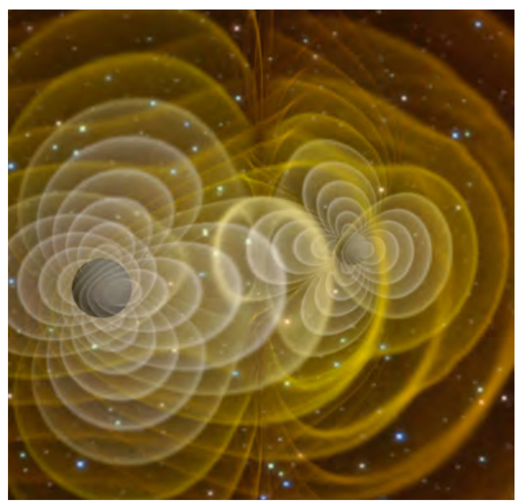
Gravitational Astrophysics Laboratory Team. From left to right: Michael Koppitz, Jim van Meter, Joan Centrella, and John Baker. Not pictured: Dae-Il "Dale" Choi (Photo credit: Chris Gunn, NASA GSFC).

grail" of the field, according to Joan Centrella, Chief of the Gravitational Astrophysics Laboratory and contributing author of a publication of the results that appeared in *Physical Review Letters*, 96, 111102 (2006). The computations were performed on the NCCS's SGI Altix 3700 BX2 supercomputer and on NASA Ames Research Center (ARC)'s Project Columbia system.

Einstein's equations for the problem, beginning with two moving black holes and ending with one (the product of their merger), are extremely complex. The end results are several useful predictions for gravitational wave astronomers. Determining the amount of the energy in the system that gets converted into gravitational wave energy is crucial for observers to know how sensitive their detectors must be. Centrella's team predicts that approximately 4% of the mass-energy in the initial black hole pair system can be converted into wave energy, and this gives observers some confidence that the waves will not be too weak to detect, even if the black hole collision occurs somewhere far away in our galaxy. The other important product of the simulations is the pattern of the wave disturbance in space and time, as a function of direction in space from the orbital plane of the initial pair of black holes.

The National Science Foundation has funded an observatory system called the Laser Interferometer Gravitational-Wave Observatory (LIGO), with component detectors in Louisiana and Washington. LIGO began full operations in November 2005. With the expected wave intensity, LIGO is estimated to have a 25% chance of detecting gravitational radiation from a celestial source in the time that it operates.

NASA has a space-based mission planned to detect gravitation radiation, called the Laser Interferometer Space Antenna (LISA), currently planned for launch around 2017. Centrella's team has provided valuable parameters for the LIGO and LISA scientists to use in their operations and mission planning.



Centrella's team crunched Einstein's theory of general relativity equations on the Columbia supercomputer to create a three-dimensional simulation of merging black holes. This was the largest astrophysical calculation ever performed on a NASA supercomputer. The simulation provides the foundation to explore the universe in an entirely new way, through the detection of gravitational waves (Image credit: Chris Henze, NASA ARC).

For the computations Centrella's team made some simplifying assumptions. The two black holes were assumed to have the same mass, and neither was spinning. Future computations can explore the effects of varying the masses in the pair and of assuming various rotational properties of one or more of the pair. The effects of these variations in initial conditions could be significant, changing the gravitational radiation output intensity and space-time distribution pattern. There is much more work to be done in this numerical relativity field.

The work at the NCCS was described by James van Meter (NRC). The team made many code development runs on the Altix, each using 64 processors for 5 hours. Many of these development runs served as the prelude to a 3-day run on Columbia with 2,032 processors, modeling five orbits of the binary black hole merger. Van Meter looks forward to operation of the NCCS's forthcoming Linux cluster (see "NCCS To Install Next-Generation Supercomputer," p.1), as he hopes to carry out more simulations typically using 500 processors.

http://www.nasa.gov/centers/goddard/universe/gwave_feature.html
http://gsfctechnology.gsfc.nasa.gov/HolyGrail.html

Scientists Confirm Historic Massive Flood Changed Climate

Scientists from NASA and Columbia University have used computer modeling to successfully reproduce an abrupt climate change that took place 8,200 years ago. At that time, the beginning of the current warm period, climate changes were thought to be contemporaneous with a massive flood of freshwater into the North Atlantic Ocean.

This work is the first to consistently recreate the event by computer modeling, and the first time that the model results have been confirmed by comparison to the climate record, which includes such things as ice core and ocean sediment data.

"We only have one example of how the climate reacts to changes, the past," said Gavin Schmidt, a NASA Goddard Institute for Space Studies (GISS) researcher and co-author on the study. "If we're going to accurately simulate the Earth's future, we need to be able to replicate past events. This was a real test of the model's skill."

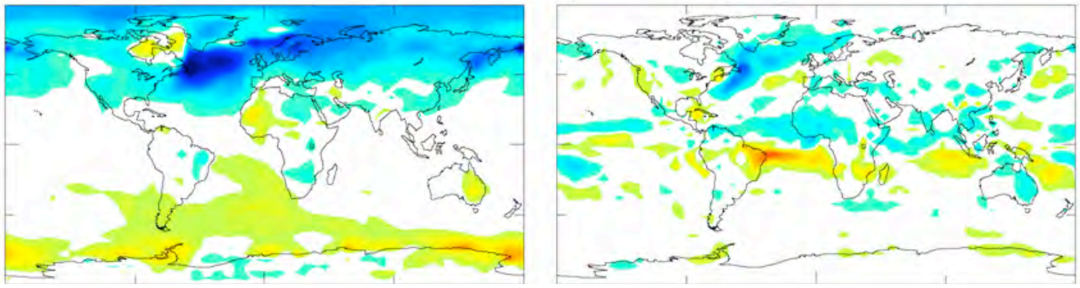
The team used the NCCS's 1,392-processor HP/Compaq AlphaServer SC45 for the ensemble simulations. Each simulation used one shared-memory node (four processors), which calculated approximately three model-years per day.

"Over the 12 simulations and controls that we used, we simulated over 3,000 model-years," Schmidt said. "With a number of false starts, adjustments, and the evolution of our research, it took about 18 months to do all the simulations."

The study was led by Allegra LeGrande, a graduate student in the department of Earth and Environmental Sciences at Columbia University. The results appeared in the journal *Proceedings of the National Academy of Sciences* (PNAS) in January 2006.

The group used the coupled atmosphere-ocean model known as GISS Model E-R to simulate the climate impact of a massive freshwater flood into the North Atlantic that happened about 8,200 years ago after the end of the last Ice Age. Retreating glaciers opened a route for two ancient meltwater lakes, known as Agassiz and Ojibway, to suddenly and catastrophically drain from the middle of the North American continent.

At approximately the same time, climate records show that the Earth experienced its last abrupt climate shift. Scientists believe that the massive freshwater pulse interfered with the ocean's overturning circulation,



A NASA Goddard Institute for Space Studies (GISS) computer model simulated the 8,200-year climate response to freshwater entering the Hudson Bay. The left and right panels show simulated changes in surface air temperature and precipitation, respectively. (Image credit: NASA GISS).

which distributes heat around the globe. According to the record of what are known as "climate proxies," average air temperatures apparently fell as much as several degrees in some areas of the Northern Hemisphere.

Climate researchers use these proxies, chemical signals locked in minerals and ice bubbles as well as pollen and other biological indicators, as indirect measures of temperature and precipitation patterns in the distant past. Because GISS Model E-R simulates several of these past climate proxies, the authors of the PNAS study were able to compare their results directly to the historical record.

The researchers prodded their model with a freshwater flow equal to between 25 and 50 times the flow of the Amazon River in the 12 model runs. Although the simulations largely agreed with records from North Atlantic sediment cores and Greenland ice cores, the team's results showed that the flood had much milder effects around the globe than many people thought.

According to the model, temperatures in the North Atlantic and Greenland showed the largest decrease, with slightly less cooling over parts of North America and Europe. The rest of the Northern Hemisphere, however, showed very little effect, and temperatures in the Southern Hemisphere remained largely unchanged. Moreover, ocean circulation, which initially dropped by half after simulated flood, appeared to rebound within 50 to 150 years.

"The flood we looked at was even larger than anything that could happen today," said LeGrande. "Still, it's important for us to study because the real thing occurred during a period when conditions were not that much different from the present day."

The GISS Model E-R is also being used for the latest simulations by the Intergovernmental Panel on Climate Change to simulate the Earth's present and future climate. "Hopefully, successful simulations of the past such as this will increase confidence in the validity of model projections," said Schmidt.

The study was funded by NASA, the National Defense Science and Engineering Graduate Fellowship program, and the National Science Foundation.

http://www.giss.nasa.gov

NCCS Supports Inaugural DICE Vendor's Day

The NCCS supported the inaugural Data Intensive Computing Environment (DICE) Vendor's Day held in Springfield, OH, on March 6. Phil Webster, CISTO's Lead for High-Performance Computing, served as the Master of Ceremonies, and more than 120 participants, representing vendors, universities, government agencies, and several private corporations, attended this very successful, ground-breaking effort.

Vendor's Day was conceived as a way to bring together members of the HPC community to identify data intensive computing needs while laying the groundwork for further development of a HPC test bed environment. The agenda included presentations and discussions detailing the overall objectives, operation, and governance of the DICE Project and presentations from user sites representing the DoD, DoE, General Electric Aircraft Engines, and GSFC highlighting their unique data challenges. The Keynote Address, "Data - Who Needs It?" was given by William Kramer, National Energy Research Scientific Computing Center (NERSC) Center General Manager. Kramer was also Chairman of the Supercomputing 2005 Conference, the premier conference for the HPC industry. Dan Duffy (CSC), NCCS Lead Architect, presented a review of GSFC's data environment, opportunities, and management issues. A highlight of the meeting was an appearance by Rep. David Hobson (R-OH) who provided his support for this innovative and cooperative effort to assist federal agencies working closer together to solve data management issues.

DICE exists to support the identification, investigation, and development of hardware and software solutions that support the demanding and unique data requirements of the HPC community. The NCCS is one of the three initial sites to form the distributed DICE test environment. The other sites are the DoD's Aeronautical Systems Center (ASC) Major Shared Resource Center (MSRC) located at Wright-Patterson Air Force Base in Dayton, OH, and the DoE's Ohio Supercomputer Center located in Springfield, OH.

Since Vendor's Day, a call for proposals addressing challenge areas was released and the submitted projects are currently under evaluation. It is anticipated that these projects will show the value of the geographically dispersed DICE test bed and the value of the technology being evaluated to find, move, and visualize data that require large data sets. Projects will be selected for use in DICE on a priority basis, subject to resource availability, and environmental suitability. A follow-up meeting is being planned for this fall.

http://www.avetec.org/dice

NCCS Holds First Users Forum

On June 6, staff held the first NCCS Users Forum to introduce the new Linux Networx Custom Supersystem to the NASA community. The live portion of the meeting occurred in GSFC's Earth System Science Building, which is home to the Earth-Sun Exploration Division and the largest group of NCCS users. Remote users accessed the meeting through the Internet and a teleconference. The forum will be a quarterly event held in various locations at GSFC.

Phil Webster, CISTO's Lead for High-Performance Computing, emphasized that the forum is designed to facilitate dialogue with users. He also presented the near-term technical direction for the NCCS, which includes the centrality of data to scientific success. Dan Duffy of CSC gave two presentations, the first providing an overview of the cluster architecture and software environment and the second detailing best practices for using the NCCS mass storage system. Tom Clune of GSFC's SIVO spoke about the training, porting, and optimization services offered by SIVO's Advanced Software

Technology Group. Sadie Duffy of CSC informed users of the processes for moving their work to the new cluster and the variety of user services available, including a new weekly user teleconference. A discussion period gave attendees the opportunity to ask questions and provide feedback. The NCCS Users Forum presentations are available at:

http://nccs.nasa.gov/user_forum.html

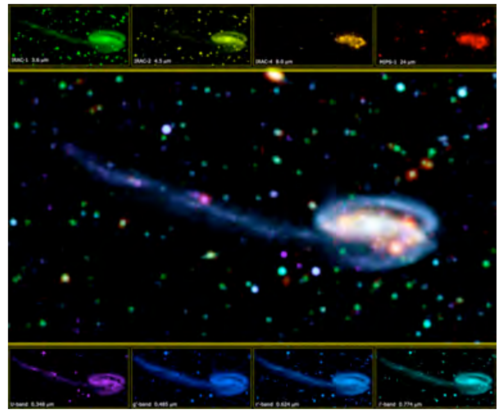
Computational Technologies Project

Montage Software Fuels Astronomical Advances

With a growing international user base, the Montage image mosaic software has become a valuable tool in the astronomer's arsenal. "It is especially good at generating products used to make discoveries," said Bruce Berriman, Project Manager of the NASA Infrared Processing and Analysis Center (IPAC) Infrared Science Archive at the California Institute of Technology (Caltech).

Montage-produced mosaics of astronomical observations can combine millions of images into seamless tapestries. Large objects such as galaxy clusters typically fall across multiple images, and mosaics allow studying these objects as complete units. NASA's Earth Science Technology Office Computational Technologies (CT) Project funded Montage development to maximize the information obtained from the many terabytes of observations taken by ground-based telescopes and NASA spacecraft.

"Different telescopes point at slightly different parts of the sky. The resolutions are different as well," Berriman said. "With Montage, you can process these images so that they have the same image parameters, point to the same part of the sky, and sample the sky at the same rate." Berriman is also project manager of the Montage development



The Spitzer Wide-area InfraRed Extragalactic Survey (SWIRE) team produced this optical-infrared panchromatic view of the Tadpole Galaxy (UGC10214), the result of a galaxy-galaxy interaction that stretched the outer spiral arm into a long tadpole-like tail. The mosaic combines several thousand infrared Spitzer images with simple, large-format optical and near-infrared images (Image credit: Tom Jarrett and the SWIRE team).

team, made up of Caltech and NASA Jet Propulsion Laboratory (JPL) researchers. Caltech astronomy professor Thomas Prince serves as principal investigator.

Since we last reported on Montage (see "Supercomputer Serves Up Giant Mosaic of Milky Way Images," *ESDCD News*, Summer 2003), the software has undergone several major improvements. Notably, Montage is up to 30 times faster than in its initial release. The speed-up is due to enhanced parallelization techniques as well as better algorithms for performing the necessary image reprojections. Montage now also includes utilities for visualizing and managing images, such as slicing a mosaic into more manageable tiles. "We didn't intend to deliver these utilities," Berriman said. "Astronomers asked us to do it."

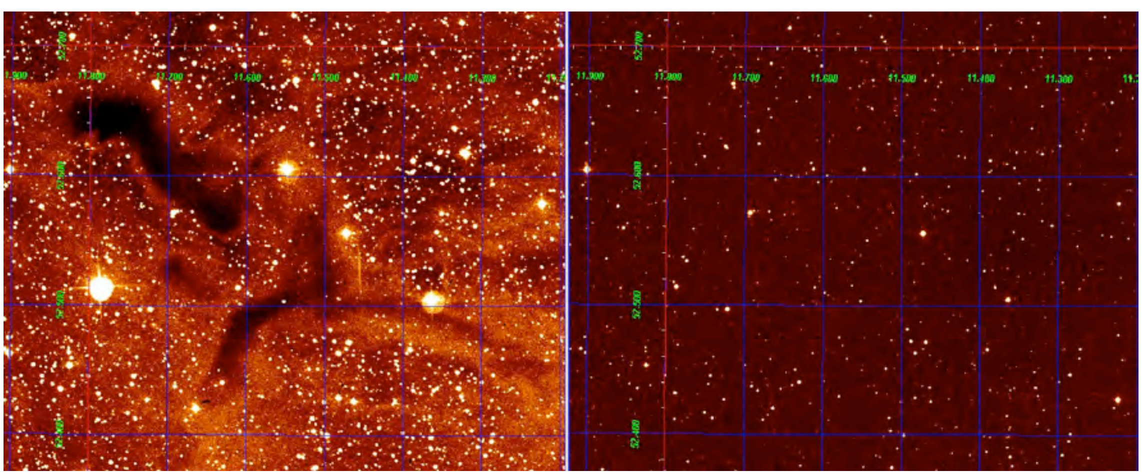
Much of Montage's success stems from its flexibility, Berriman said. It offers user choice with independent portable modules that can run on a variety of computing environments, including workstations, clusters, supercomputers, and grids. The Montage team has joined with the University of Southern California's Information Sciences Institute to implement Montage on TeraGrid, the most powerful distributed computing environment in the world. This National Science Foundation-funded resource links over 40 teraflops of computing power, nearly 2 petabytes of mass storage, and data analysis and visualization tools over a dedicated 10- to 30-gigabit-per-second national network.

On the TeraGrid, Montage is currently available as a Web service for evaluation by astronomers. The service creates mosaics from three multi-terabyte image databases: the Two Micron All Sky Survey (2MASS), the Digitized Palomar Observatory Sky Survey (DPOSS), and the Sloan Digital Sky Survey. Testers' feedback will help tweak the software for a public service on the IPAC and National Virtual Observatory Web sites, with a debut expected in late summer.

Whether through the TeraGrid or other means, scientists across the United States and in other countries are harnessing Montage's capabilities. Their applications are as varied as finding new galaxies, probing star-forming regions, and creating an all-sky map.

The most extensive Montage users come from the NASA Spitzer Space Telescope Legacy Teams. As Berriman explained, "The Spitzer Science Center funded data teams and gave them generous observing time on Spitzer. In exchange, they give early public access to data sets. Legacy implies the value of the data." Spitzer is an infrared telescope with its own internal repository, but the data will eventually come over to the IPAC Infrared Science Archive.

One of the legacy teams using Montage is the Spitzer Wide-area InfraRed Extragalactic Survey (SWIRE), which consists of American and British researchers. SWIRE aims to discover new galaxies at redshifts of 2 to 3, or 3.4 billion to 2.2 billion years old given the best-estimated age of the universe. SWIRE has imaged 49 square degrees of the sky, "equivalent to the area covered by about 250 full moons," said IPAC astronomer Jason Surace. The Spitzer observations come in seven infrared and near-infrared wavelength bands. Comparative optical observations come from the Isaac Newton Telescope in La Palma, Spain. The SWIRE team uses Spitzer's MOPEX mosaic tool for their own data and Montage for the optical data



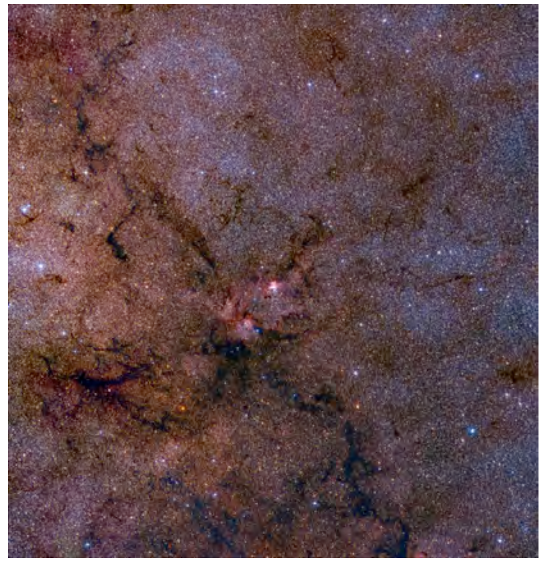
Caltech's Michelson Science Center (MSC) created these mosaics of a molecular cloud, where stars can form. The left-hand mosaic uses two observations from the optical Digitized Palomar Observatory Sky Survey (DPOSS). The right-hand mosaic incorporates 75 images from the infrared Two Micron All Sky Survey (2MASS). The optical mosaic clearly shows the cloud boundaries, demonstrating the utility of aligning different types of survey data and placing them on the same pixel scale (Image credit: David Ciardi and the MSC team).

and comparisons.

“Various Montage tool modules are scripted to mass-process up to thousands of optical observations and then match the projection, scale, and section of the sky in the Spitzer data mosaics,” Surace said. The team then incorporates the mosaics into multi-band visualization tools to show features across wavelengths. “Having all these data in the same reference frame makes comparison on objects across bandpasses trivial, whereas prior to mosaicking, comparison of objects across different scales and projections was too complex and at times not even possible,” Surace said.

Scientists at Caltech’s Michelson Science Center (MSC) have been using Montage to produce mosaics of molecular clouds and star-forming regions. MSC uses 2MASS and DPOSS images in their mosaics. “By creating single images for multiple filters, all registered to the same coordinate system over many degrees, Montage can enable detailed studies of the large-scale distribution of the mass of the clouds and the positions and evolutionary status of young stellar objects over the extent of the molecular clouds,” said MSC’s David Ciardi. “Without a mosaicking tool such as Montage, studies are generally limited to smaller fields of view or to catalog photometry from sky surveys such as 2MASS, which may not accurately reflect the presence of extended emission around young stellar objects.”

Researchers at one of the TeraGrid sites, the San Diego Supercomputer Center (SDSC), have collaborated with the Montage team to build an all-sky map that encompasses the full 2MASS data set—8 terabytes. Berriman describes the effort as a “computational tour de force.” SDSC processed the 2MASS mosaics using as many as 1,000 or more processors at a time. Even with Montage’s improved performance, combining more than 4 million 2MASS images took approximately 130,000 processor hours, which included time to shake down the TeraGrid hardware. The final product consists of 5,202 mosaics, with a total size of 20 terabytes.



This mosaic shows dust clouds and nebulosity in the plane of our Galaxy, as derived from images in the 2MASS Second Incremental Data Release. It combines 347 images observed in three near-infrared bands. The full-scale mosaic (this reduction is 1/24 the resolution) contains 12,000 individual pixels on a side (Image credit: Montage team).

“The Montage team is using this all-sky computing project to learn how to manage image processing at scale while generating scientifically valuable products,” Berriman said. “The initial results are very promising and show that available hardware and software do indeed support large-scale processing. The Montage team is now investigating the scientific value of the all-sky mosaics to ensure that calibration accuracy is preserved and that background rectification is successful across the sky. Ultimately we hope that our investigations have applicability to future astronomical missions and surveys that require image processing at scale.”

Montage team members include Tom Prince, Bruce Berriman, Anastasia Clower

Laity and John Good at Caltech; Joseph Jacob and Daniel Katz at JPL; and Ewa Deelman, Gurmeet Singh, Mei-Hui Su, and Carl Kesselman at the University of Southern California.

http://montage.ipac.caltech.edu
http://swire.ipac.caltech.edu
http://ct.gsfc.nasa.gov

Networks & IT Security

Network Infrastructure Upgraded to 10-Gbps

Recognizing the demand for reliable high-speed networks to support the HPC community and its projected data flow requirement increases, the Scientific and Engineering Network (SEN) and the NCCS each upgraded their network infrastructures to 10 gigabit per second (Gbps). These upgrades capitalize on the wide-area NASA Research and Engineering Network (NREN) upgrade, which increased the bandwidth in its backbone link between GSFC and ARC's Project Columbia from 1 Gbps to 10 Gbps using the National LambdaRail (NLR).

The SEN's perimeter router began operationally supporting a 10-Gbps connection from the NREN's GSFC-local 10-Gigabit Ethernet (GE) switch/router in March. In the weeks prior, CISTO's Bill Fink assisted the NREN in stress testing the new 10-Gbps lambda-based connection obtained from the NLR by generating 9.2-Gbps of User Datagram Protocol (UDP)-based Internet Protocol (IP) packets between two pairs of SEN-based computers, but where the data traffic between those pairs was looped out to Sunnyvale, CA and back. In several 6-hour duration tests of the new connection, the NLR never lost a packet, and the NREN Project accepted the link for operational use.

In April, the NCCS began pre-operational end-to-end readiness tests of its 10-Gbps network infrastructure, which includes multiple 10-GE ports on a new switch/router and 10-GE network interface cards (NICs) for several NCCS supercomputer platforms. End-to-end single-stream TCP-based IP packet flow testing between an NCCS SGI Origin 3800 and a not-fully-tuned high-performance workstation at ARC across the 10-Gbps NREN demonstrated up to 1.5-Gbps throughput performance, and testing with two simultaneous TCP-based streams demonstrated up to 3.0-Gbps throughput performance.

Operational cut over of several more NCCS supercomputer platforms to NCCS's 10-GE network infrastructure is planned for early June.

In recent presentations made to the Sciences and Exploration Directorate's Data Archive and Distribution for High-performance Computing Working Group, Christa Peters-Lidard, Head of the Hydrological Sciences Branch, concluded with the prediction, "NASA science will be bandwidth limited – not CPU limited." Mike Seablom, Head of SIVO, added, "Now and beyond, data and networking are the central elements to enable faster leaps in performance." The 10-Gbps upgrades of the NREN, SEN, and NCCS network infrastructures will help fulfill those predictions.

http://cisto.gsfc.nasa.gov/SENuser.html
http://www.nccs.nasa.gov

CISTO Newsmakers

Scientists Discover Newly Forming Solar System with Bi-directional Orbits

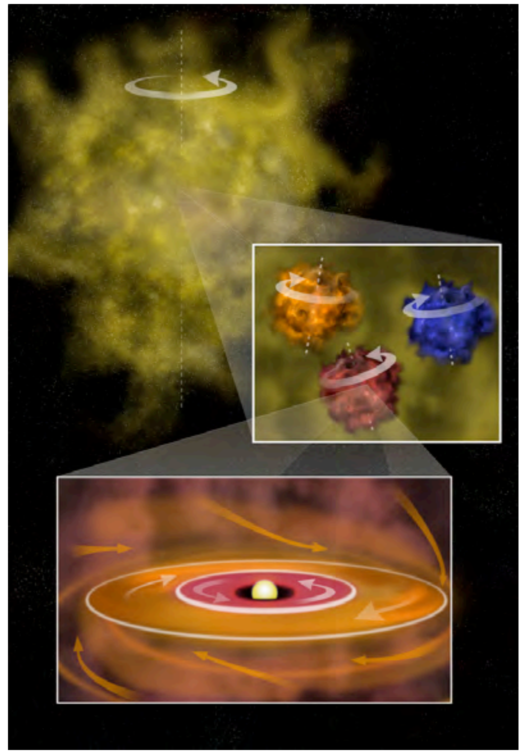
Astronomers studying a disk of material circling a still-forming star inside our galaxy have found a tantalizing result—the inner part of the disk is orbiting the protostar in the opposite direction from the outer part of the disk.

"The solar system that likely will be formed around this star will include planets orbiting in different directions, unlike our own solar system in which all the planets orbit the Sun in the same direction," said CISTO senior scientist J. Michael Hollis.

"This is the first time anyone has seen anything like this, and it means that the process of forming planets from such disks is more complex than we previously expected," said Anthony Remijan, a former CISTO post-doctoral researcher now at the National Radio Astronomy Observatory. Remijan and Hollis used the National Science Foundation's Very Large Array (VLA) radio telescope to make the discovery.

Stars and planets, scientists believe, are formed when giant clouds of gas and dust collapse. As the cloud collapses, a flattened, rotating disk of material develops around the young star. This disk provides the material from which planets form. The disk and the resulting planets rotate in the same direction as the original cloud, with the rotation speed increasing closer to the center, much as a spinning figure skater spins faster when they draw their arms inward.

If all the material in the star and disk come from the same prestellar cloud, they all will rotate in the same direction. That is the case with our own solar system, in which the planets all orbit the Sun in the same direction as the Sun itself rotates on its axis.



Top view: A huge star-forming region is rotating globally in the direction shown by the white arrow. This large region can give birth to multiple stellar systems. Middle view: A detailed view inside the large star-forming region shows three protostars forming as the region collapses. The collapse process is chaotic and can cause eddies, allowing newly-forming stars to rotate in different directions and at different speeds, as shown by the arrows. Bottom view: One protostellar cloud collapses further into a disk-like structure that rotates counter-clockwise (white arrows) about the newly-formed protostar. In addition, the protostar siphons off material from a second, passing protostellar cloud rotating in the opposite direction. Because of this process, the outer part of the disk rotates clockwise (yellow arrows). Eventually, planets will form from the material in this disk, with the outer planets orbiting the star in the opposite direction from the inner planets (Image credit: Bill Saxton, NRAO/AUI/NSF).

In the case of a young star some 500 light-years from Earth in the direction of the constellation Ophiuchus, Remijan and Hollis found the inner and outer parts of the disk rotating in opposite directions.

"We think this system may have gotten material from two clouds instead of one, and the two were rotating in opposite directions," Remijan said. There is sufficient material to form planets from both parts of the disk, he added. The object is in a large, star-forming region where chaotic motions and eddies in the gas and dust result in smaller cloudlets that can rotate in different directions.

In the solar system that probably will form around this young star, the innermost planets will orbit in one direction and the outer planets will orbit in the opposite direction.

The scientists studied the star-forming clouds by analyzing radio waves emitted at specific, known frequencies by molecules within the clouds. Because the molecules emit radio waves at specific frequencies, shifts in those frequencies caused by motions (called Doppler Shift) can be measured, revealing the direction in which the gas is moving relative to Earth.

The newest VLA observations of the region showed the motion of silicon monoxide molecules, which emit radio waves at about 43 GigaHertz. When the astronomers compared their new VLA measurements of the motion of silicon monoxide molecules close to the young star with earlier measurements of other molecules farther away from the protostar, they realized the two were orbiting the star in opposite directions.

Although this is the first time such a phenomenon has been seen in a disk around a young star, "Similar structures and dynamics commonly occur on small and large scales throughout the universe," said Hollis. "Thus, it is not surprising to find counter-rotation in a protostellar disk since the phenomenon has been previously reported in the disks of galaxies."

The astronomers' results appeared in the April 1 edition of the *Astrophysical Journal*.

The National Radio Astronomy Observatory is a National Science Foundation facility operated under cooperative agreement by Associated Universities, Inc.

http://www.nasa.gov/centers/goddard/news/topstory/2006/opposite_orbit.html
http://www.nrao.edu/pr/2006/counterdisk

Computer Scientist Receives 2006 Kerley Award from Office of Technology Transfer

On April 4, GSFC's Deputy Director Michael Ryschkewitsch presented James Tilton, a computer scientist of CISTO's Information Science and Technology Research group, with the GSFC Office of Technology Transfer's James Kerley Award. Presented annually, the award is named after the late James Kerley, a GSFC researcher who was a prolific inventor and a champion of technology transfer. Tilton received the 2006 Kerley Award for his efforts to find new uses for a software program he originally developed for remote sensing applications.

Tilton's innovation, the Hierarchical Segmentation (HSEG) software, provides a new approach to image analysis. Rather than analyzing the image on a pixel-by-pixel basis, this software organizes the image pixels into regions. "Looking at the regions instead of the individual pixels allows the user to iso-

2006 Kerley Award winner James Tilton (center) pictured with members of the Kerley family at the GSFC Office of Technology Transfer's 14th Annual New Technology Reporting Program (Photo credit: Debora McCallum/GSFC).

late specific features that otherwise are impossible to distinguish," explained Ryschkewitsch. For example, in a satellite image, the software can indicate different types of vegetation, distinguishing a golf course from a park from the woods."

The HSEG software, and its follow-on known as "RHSEG" (Recursive Hierarchical Segmentation), have a broad spectrum of applications and have been incorporated into a commercial medical imaging product (see "CISTO Engineer Receives Patent and IS&T Award," *CISTO News*, Summer 2005). The software is now being used to assist in the diagnosis and management of diseases that are imaged using digital x-rays, mammograms, ultrasounds, MRI images, and CAT scans. Other non-medical applications for HSEG/RHSEG include agricultural crop monitoring, identifying population densities and areas with greatest expansion, facial recognition, and data mining.

http://www.nasa.gov/centers/goddard/pdf/147429main_GV2_7_Web.pdf
http://techtransfer.gsfc.nasa.gov/SS-rhseg.html